Transparent substance is one that does not absorb electromagnetic radiation in the visible spectrum. Absorption of radiation involves a loss of energy in the radiation and a gain of energy in the substance. This gain in energy in the substance is translated partly into kinetic energy, thermal energy (caused by the motion due to the kinetic energy) and electron energy levels and the bonds between the particles themselves.

Most energy absorbed involves the substance's atoms. The amount of energy it takes to affect the atom is related to binding energy between the nucleus and the electrons. Loosely bound electrons (valence electrons) can be excited by visible or ultraviolet radiation. As the radiations frequency increases or the wavelength decreases, the radiation affects the more closely bound electrons down to the nucleus itself.

Another factor is the chemical structure of the material. Crystalline structures like salt are not transparent because the orientation of the crystals refract, reflect and scatter the electromagnetic waves. A single crystal (diamond) is transparent though. In amorphous materials like glass the chemical bonds are random therefore there is no structure plains to refract the electromagnetic waves. An exception to this is metals, they are amorphous but since they can conduct electricity (loose electrons, their effects mentioned above) they are not transparent.

Glass is an amorphous material that is not conductive, so these are other reason glass is transparent. Transparency is not only affected by the electron bonds and the structure of bonding. The substance must be free of bubbles, chemical structure differences and other foreign material to be transparent. These imperfections cause reflection and scattering of the radiation and a decrease in transparency. Glass's electrons are tightly bound to the nucleus; therefore its electrons are not excited by radiation in the visible spectrum. Plus glass is an amorphous material and an insulator so it is transparent. Much work has been done on removing the impurities in glass to increase the transparency. Although glass is transparent it does absorb other electromagnetic radiation, in the infrared and ultraviolet wavelengths.

Question - Since ultraviolet light has relatively short wavelength compared to infrared, and shorter wavelengths are supposed to have more penetrating ability than longer ones, why is it that ultraviolet light does not go through glass as well as does infrared?

Answer

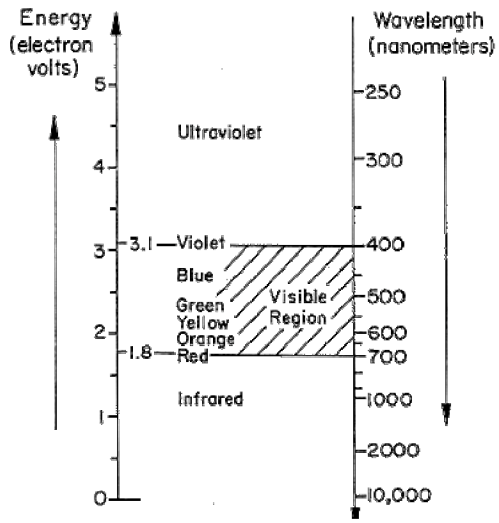
Your assumption that "shorter wavelengths are more penetrating longer ones" is not universally true. Every material has a specific characteristic range of electromagnetic radiation to which it is transparent, partially opaque, or almost totally opaque. The atmosphere for example is almost entirely transparent to visible light, absorbs part of the incident infrared from the Sun, and part of the incident ultraviolet (called UV-A and UV-B) that causes sunburn.

The physics of the transmission of electromagnetic radiation can get pretty complicated. Glass that is surface treated can be very transparent in the visible part of the spectrum, but highly reflective in the infrared. Such treated glass is used as insulators in buildings.

Let me try to give you more perspective. To say that "shorter wavelengths have more penetrating power" across the whole E-M wave spectrum is an oversimplification. It is only true in the high-energy range, past ultraviolet, called X-rays and gamma rays. In that range it is true because each photon has higher energy than the chemical bonds it breaks or the bound electrons it frees in the process of losing energy to the matter it is passing through. In that range matter almost rarely absorbs a whole photon in one absorption event, it just nibbles the photon down to lower and lower energies. In that range, it takes more nibbles to reach a low energy where the remaining photon is finally absorbed, so "the photon", though changed, penetrates farther.

In long wavelength ranges, shorter wavelength means a better match to the electronic resonances or energy levels of matter; so ultraviolet is actually the least penetrating wavelength range in the whole electromagnetic spectrum. Especially "VUV" (Vacuum Ultraviolet), wavelengths of 0.2 micron (photon=6eV) to maybe 0.002 micron (photon=600eV)

Most of the space in matter, as these waves try to penetrate, is the territory of molecular-orbital electrons, outer-shell electrons with resonant absorption energies of 4-20 eV. Photons at the top end of this energy range interact rabidly with any bound electrons they pass near, losing their energy in small fractions of a micron in solid matter. They are even absorbed quickly in gasses such as air. They only survive in a vacuum, hence the name "VUV".



In very high energies like X-rays and gamma rays, the photon's wavelength starts getting smaller than the distance between two atoms, so it's also possible for the photon to be localized in the space between atoms, rather than being a broad wave front immersing many atoms at once.

Think about the long-wavelength end of the spectrum, too. Long radio waves can go through miles of the best non-conductive substances, to distances of roughly 10,000 wavelengths. In that range, longer wavelengths have more penetrating power.

DC magnetic fields might be considered waves of photons of sub-1Hz frequencies. They are very penetrating if the substance does not have magnetic atoms like iron, and sometimes even when it does. The earth's polar magnetic field is an example; it penetrates a thousand miles of crust and mantle.